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Research Paper

Channel Estimation Techniques Used in OFDM System for Different Modulation Techniques: an Overview

Engineering

KEYWORDS : OFDM, QAM and PSK modulations, Least square error, Minimum mean square error, EP, PACE.

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ABSTRACT

To recover accurate transmitted data at the receiver end, the information regarding channel state derived from channel estimation methods play a very important role in any communication system. In this paper the performance evaluation of different types of quadrature amplitude modulation (QAM) and phase shift keying modulations, Least Square (LS), Minimum mean square error(MMSE), Evolutionary Programming, PACE and DFT based channel estimation methods in Orthongonal frequency division multiplexing system for different modulation techniques in wireless communication is discussed.

1 INTRODUCTION

Wireless communication and transmitting data have many demands these days and are used in many applications. Wireless communications have many problems and restrictions. Channel estimation and destruction by channel, power limitation of transmitted data, complexity of mobile receivers, band width limitation that should be distributed between some users, are some of these problems. Among of wireless techniques, orthogonal frequency division multiplexing (OFDM) has many advantages and especially is noticed in frequency selective Rayleigh channels. OFDM is a general technique in signal transmission on the wireless communication. This technique converts a frequency selective channel to a collection of flat frequency selective sub-channel that leads to simplicity of receiver structure [1]. In these systems, inter-symbol interference (ISI) can be removed by using of cyclic prefix (CP). Cyclic prefix is inserted between consecutive transmitted blocks and should be increased beyond the maximum delay expansion of channel. A good delineation of this parameter leads to simpler channel synchronization and the effect of channel appears as a simpler scalar multiplication in the frequency domain. Hence each subcarrier is attenuated by the corresponding narrowband sub-channel coefficient. A title of an orthogonal frequency division multiplexing (OFDM) is an efficient high data-rate, having advantages of high spectrum efficiency, simple & efficient implementation by using the fast Fourier transform (FFT) & the inverse FFT (IFFT), mitigation of inter symbol Interference by inserting a cyclic prefix (CP) and robustness to frequency selective fading channels transmission technique for wireless communication[2].

2 OFDM SYSTEM

In OFDM systems, data is transmitted on narrow-band subcarriers in frequency domain. Fig- 1 shows some of these subcarriers in frequency domain. Sub-carriers have overlap in frequency domain, hence frequency efficiency is increased. If subcarriers are completely orthogonal, inter-channel interference (ICI) can be removed.

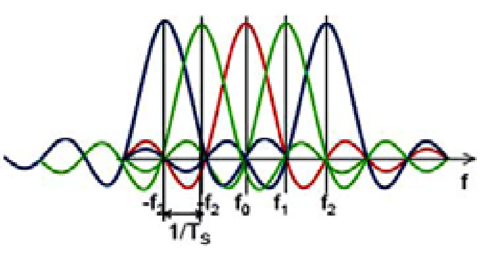


Figure 1: Sub-carriers in an OFDM system [3]

Figure-2 shows block diagram of an OFDM system. In this system, after pilot insertion between data sequence at the transmitter, the result data is modulated by inverse discrete Fourier transform (IDFT) on N parallel subcarriers and then after receiving signal at receiver transformed back to frequency domain by DFT. In fact, IDFT converts frequency domain data into time domain. The number of points of the IDFT/DFT is equal to the total number of sub-carriers. Every subcarrier can be formulated as follow:

$$S_c(t)=A_c(t)\, e^{i[wct+\phi c(t)]} \tag{1}$$

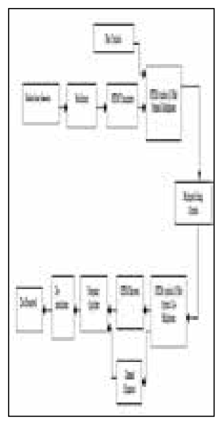


Figure 2: OFDM System block diagram [6]

Where, Ac (t) is amplitude and Φ c (t) is phase. An OFDM signal is constructed from some of these subcarriers, so it can be described as follow:

$$SS(t)=\frac{1}{N}\sum_{n=0}^{N-1} An(t)\, e^{j[Wn+\varnothing n(t)]} \tag{2}$$

Where, wn=wo+nΔw

Ac (t) and Φ c (t) get different values in different symbols, but they are constant in every symbol and only depend on frequency of carriers. It means that we have in every symbol.

In continuation cyclic prefix is inserted. Cyclic prefix is a crucial feature of OFDM that is used to prevent the intersymbol interference (ISI) and inter-channel interference (ICI). ISI and ICI are produced by the multi-path channel through which the signal in propagated. Cyclic prefix protects orthogonality between subchannels. The duration of the cyclic prefix should be longer than the maximum delay spread of the multi-path environment. For adding cyclic prefix, a part of the end of the OFDM time-domain waveform is added to the front of it. Cyclic prefix is caused that circular convolution is converted to linear convolution. Therefore the effect the channel on each subcarrier can be presented by a single complex multiplier. The frequency selective channel is modeled as a finite impulse response (FIR)filter.

Gaussian random process with zero mean and unit variance, and λl is the delay of the ith path. Transmitted data, after passing through the channel and adding noise, is received as follow:

$y(n)=s(n) \otimes h(n)+w(n)$ (3)

Where, y is received signal, s is transmitted data, and ω is additive white Gaussian noise. Equation (4) shows received signal after removing cyclic prefix and applying FFT on it.

$Y(k)=S(k)H(k)+W(k)$ (4)

That W and H are the Fourier transform of the noise and h respectively.

In continuation, the channel is estimated in pilot subcarriers, and then whole channel frequency response is obtained by interpolation. And finally, data is detected as follow:

$X(k)=\frac{Y(k)}{H(k)}$ (5)

Where, Y (k) is Fourier transform of y (n) . X (k) and H(k) are transmitted data and estimated channel respectively[3].

3 DIFFERENTCHANNEL ESTIMATION TECHNIQUES

One of the objectives of receiver design is to minimize the detection error. In general, the design of optimal detector requires the knowledge of the channel. Often unknown in practice, channel parameters need to be estimated, preferably using only a limited amount of data samples. In communication applications, especially for packet transmissions, the efficiency (a measure of how effectively an algorithm utilizes the available data) of the estimator is particularly important [4].

We consider different types of channel estimation here. First technique of channel estimation refers to the estimation of the transmitted signal bits using the corresponding received signal bits. Among different channel estimation methods, least square (LS) and minimum mean square error (MMSE) method are most commonly used. In LS, the estimation procedure is simple but the problem is that it has high mean square error. In Low SNR, the MMSE is better than that of LS, but its main problem is its high computational complexity. To overcome these problems, here a new method is proposed by combining LS and MMSE method using Evolutionary Programming. In this method, three stages of Evolutionary Programming are used. In the first and second stages, mutation operation is applied in LS and MMSE channel respectively and in the third stage, crossover operation is applied between the LS and MMSE channel, followed by a mutation operation. Then one best channel estimation matrix is selected among the three estimation matrices that are obtained after the completion of three stages of evolutionary programming. New channel estimation generated after crossover operation is [5]:

{[H11,H12],[H21,H22],[Hr1,Hr2]} (6)

Second technique is a comparative study of different types of quadrature amplitude modulation (QAM) and phase shift keying (PSK) modulations with least square (LS), linear minimum mean square error (LMMSE) and modified minimum mean square error (Mod MMSE) channel estimation techniques applied to OFDM systems for the purpose of detecting the received signal, improving the throughput of orthogonal frequency- division multiple – access (OFDMA) systems. Modified channel transfer function is[6] :

HMMSEMod=AModHLS,

Where AMod=RHHMod(RHHMod+Iβ/SNR)-1 (7)

Third technique is application of DFT on LS, MMSE channel estimation can improve the performance of estimators by eliminating the effect of noise. In OFDM system, the length of the channel impulse response is usually less than the length of the cyclic prefix L. DFT-based algorithm uses this feature to increase the performance of the LS and MMSE algorithms. It transforms the frequency channel estimation into time channel estimation using IDFT, considers the part which is larger than L as noise, and then treats that part as zero in order to eliminate the impact of the noise. Taking the IDFT of the channel estimate [7]

$\{\hat{H}[k]\}_{k=0}^{N=1}$,

IDFT$\{\hat{H}[k]\}$=h[n]+z[n]$\otimes\hat{h}[n]$,n=0,1..N-1 (8)

Taking the DFT remaining L elements to transform in frequency domain [7]

HDFT[k]=DFT{hDFT(n)} (9)

Fourth technique is the channel estimation is based on the principle of pilot-symbol aided channel estimation (PACE), and it has been implemented using comb-type and block-type pilot subcarrier arrangements. The algorithms used there are based on the least squares (LS) and the linear minimum mean-square error (LMMSE) approaches supported by linear and cubic interpolation, and an IFFT-based time channel estimation, which uses a zero-padding interpolation approach with and without Wiener filtering. In frequency domain algorithms, phase compensation is also taken into account. Bit error rate (BER) versus signal-to-noise ratio Eb/N0 results show that the frequency based methods generally perform better than the corresponding time based ones. Phase compensation is required in comb-type pilot sub-carrier arrangement when a low number of pilot sub-carriers is used. The estimated channel can be written as[8]

$$\hat{H}_{LMMSE}=\frac{R_{\hat{H}\hat{H}}\left[R_{\hat{H}\hat{H}}+\left[\frac{E_b}{N_0}\right]^{-1}I\right]^{-1}\hat{H}_{LS}}{Z} \quad (10)$$

4 RESULTS DISCUSSION

Results show that on different types of technique methods. From this first technique is the channel estimation technique was implemented in MATLAB 7.11 and its performance is analyzed using SNR vs. mean square error graph. Results are analyzed by changing the number of iterations, mutation and crossover rate. SNR vs mean square error graph is plotted for channel model obtained after applying mutation in LS channel, MMSE channel and crossover operation between LS and MMSE channel, followed by mutation operation respectively. The best channel is selected based on the minimum error value. From the performance results, it is clear that which method is better than the other existing LS and MMSE methods. The method is analyzed by changing the number of iteration, mutation rate and crossover rate. From Figure3 result is given [5]. Second technique is quadrature amplitude modulation (QAM) and phase shift keying (PSK) modulations in frequency domain estimation the use of LMMSE estimator performs significantly better than the LS estimator and modified MMSE gives better or equivalent performance with suitable significant number for channel weight matrix. The modified MMSE has a significant advantage of reduced computational complexity. Further, the results showed that symbol error rate increases with the higher order of modulations and PSK modulations involved lesser computations than QAM modulations. Figure 4 shows the result of it [6]. In technique-3, Simulations are carried out for channel estimation using LS-Linear, LS-spline, MMSE methods. The Simulation results show that the performance of DFT based channel estimator is much better over the LS, MMSE estimator. It is observed that simulation results become better if the estimated output from various estimators is subject to DFT. Simulation results show that MMSE with DFT performs better than other estimations at the cost of computational complexity. Figure 5 shows the result of it [7]. In fourth technique, Comparing time and frequency based algorithms, we could claim that frequency based methods give better results than time based methods for most of the used pilot sub-carrier sets (32, 64, 128). The improvement is in order of 2 – 4 Db. The use of an LS estimator with linear interpolation appears to be the best choice. Simulation result shown in Figure 6 [8].

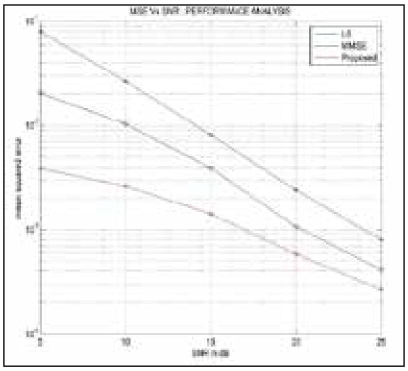
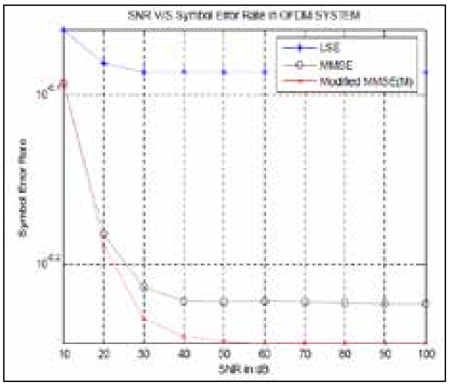
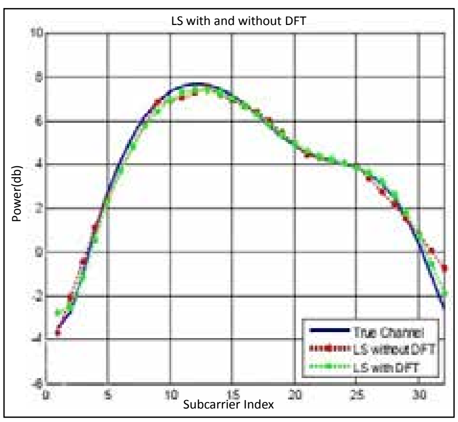


Figure 3:Comparison graph between proposed, LS and MMSE channel model at r=50, M=0.02 and C=0.5[Figure 4Performance



comparison of 64PSK symbol error rate [6]. Figure5: Perfor-



mance of MIMO-OFDM System Using LS-Linear Channel Estimation with and without DFT for QPSK at SNR 30 dB [7].

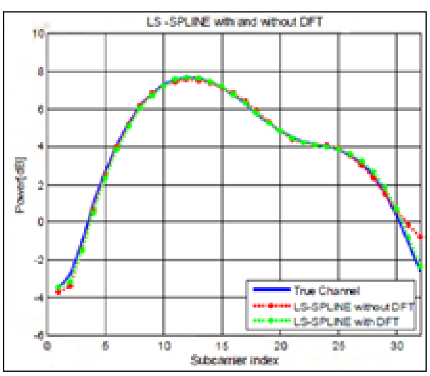
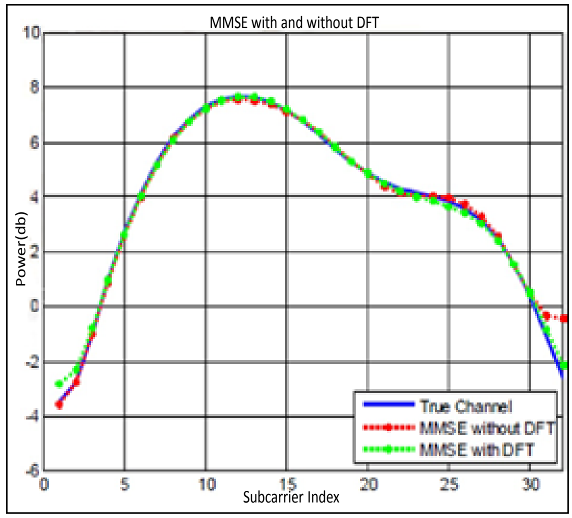


Figure 6:Performance of MIMO-OFDM System Using LS spline Channel Estimation with and without DFT for QPSK at SNR 30 dB [7].

Figure 7Performance of MIMO-OFDM System Using MMSE



Channel Estimation with and without DFT for QPSK at SNR 30 dB [7].

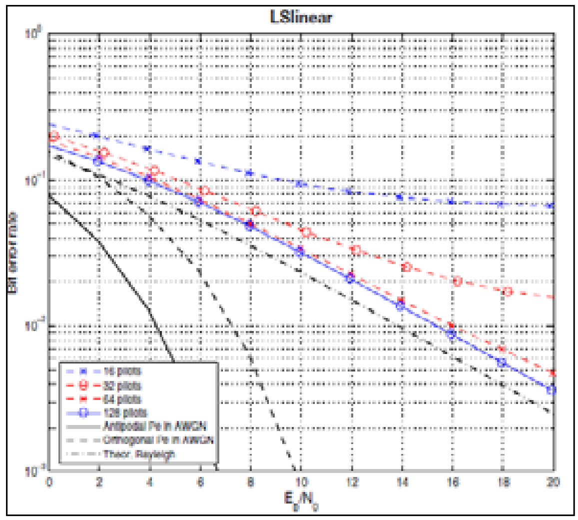


Figure 8: BER vs. SNR for LS estimation for different number of subcarriers with linear interpolation [8].

5 CONCLUSION

Results show different methods here. From these results, the first technique channel estimation method for OFDM by combining LS and MMSE using Evolutionary Programming was proposed. First, LS and MMSE channel model is estimated and three stages of evolutionary programming is applied in LS and MMSE channels. The best channel obtained in each stage of Evolutionary Programming is selected. Best channel with minimum error is selected from the three best channels that are obtained from three stages of Evolutionary Programming. This method is analyzed by changing the number of iteration, mutation rate and crossover rate. Second technique is that in frequency domain estimation the use of LMMSE estimator performs significantly better than the LS estimator and modified MMSE gives better or equivalent performance with suitable significant number to the

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